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Passive Ozone Network of Dallas: A Modeling Opportunity with Community Involvement. 2

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Attaining the current lower tropospheric U.S. ozone standards continues to be a difficult task for many areas in the U.S. Concentrations of ozone above the standards negatively affects human health, agricultural crops, forests, and other ecosystem elements. This paper describes year two (1999) of a regional networking of passive and continuous ozone monitoring sites in the Dallas−Fort Worth (DFW) Metroplex region. The objectives of the second year of study were to (1) validate conclusions of the 1998 Passive Ozone Network of Dallas (POND) I study, (2) define the value of taking 12-h diurnal samples in addition to 24-h samples, and (3) add to the scientific knowledge base of rural/urban ozone comparison studies. Results of the POND II (1999) study demonstrated that ozone concentrations exceeding the new 8-h ozone standard could be recorded at least 130 km, or 80 miles, from the DFW Metroplex core in more rural areas. In addition, results of the POND II study indicated that ozone concentrations exceeding the 8-h standard probably occurred in areas recording a 12-h daytime ozone concentration above 60 parts per billion (ppb). The 12-h passive ozone data from POND II also suggests the relative magnitude of anthropogenic pollution influence could be assessed for rural passive ozone sites. The data from the POND II study provide modelers a rich database for future photochemical subgrid development for the DFW ozone nonattainment area. Indeed, the POND database provides a great amount of additional ozone ambient data covering 26 8-h and 13 1-h ozone standard exceedance days over an approximate 25 000 km^2 region. These data should help decrease uncertainties derived from future DFW ozone model exercises.

1. Introduction

Lower tropospheric ozone continues to be a very difficult pollutant to control in many urban and rural areas, significantly impacting human health, agricultural crops, forests, and natural ecosystems (*1, 2*). Despite progress in lowering peak hourly ozone concentrations over the past 20 years, 8-h ozone concentrations in some rural and national park areas have increased in the past 10 years (*3*). In 1997, responding to scientific evidence showing adverse health and welfare effects at longer averaging times, the U.S. Environmental Protection Agency (EPA) finalized a new 8-h ozone standard, set at 0.08 parts per million (ppm) and compared to a rolling 3-year average of the fourth highest annual 8-h daily maxima (*4*).

The four county urban core of the DFW Metroplex (Dallas, Tarrant, Collin, and Denton Counties) is one of the areas in the U.S. that does not meet either the 1-h ozone standard (set at 0.12 ppm for a maximum daily hourly average, not to be exceeded more than once per year over a 3-year period) or the more recent 8-h ozone standard. The DFW Metroplex contains an estimated five million people (*5*) and encompasses a significant amount of agricultural land (*6*). The work reported herein describes year two of an extensive ozone passive/continuous monitoring network in and surrounding the DFW Metroplex that was operated by public volunteers during 6 weeks of the 1999 high ozone season. Passive ozone samplers have been used in previous studies, albeit not with an emphasis upon a daily sampling regime in a large geographical region, and have provided valuable ozone concentration trends in remote areas where continuous ozone measurements are not currently practical (*7, 8*). The work had the following objectives: (1) to validate conclusions from the 24-h passive ozone sampling database (30 passive ozone sites; 2880 readings) taken during the 1998 POND I study; (2) to explore the value added of 12-h diurnal samples taken in addition to 24-h samples; and (3) to add to the knowledge base of rural/urban ozone comparison studies on a regional basis.

2. Methods

The POND II study focused upon the same area (i.e. 25 000 km^2) as the POND I study (*9*), but with the important inclusion of three continuous ozone monitors by Oklahoma (OK) at sites bordering the state line of north-central Texas and proximate to rural POND sites (Figure 1). The State of Oklahoma deployed these three sites in order to gather more information on ambient ozone concentration transport from the DFW area to rural southern Oklahoma during periods of predominant southerly winds. The OK data also helped in the interpretation of the passive ozone data generated by sites between the DFW Metroplex core and the Oklahoma/Texas Red River area. Including the three additional OK sites, network data from 22 monitoring stations were analyzed for POND II, which included nine passive ozone stations plus one collocated passive/continuous ozone urban station in Arlington (site #4). As in the POND I study, site operators included volunteers from EPA Region 6 personnel, service organizations such as the 4-H Club and Master Gardeners, as well as farm retirees recommended by county extension agents. No effort was made to specifically enlist people of any defined background or age bracket. The directions used for setting up the passive ozone concentration sampling poles in the POND II study were identical to those used in the POND I study (*9*). Each pole assembly stood about 4 feet above the ground.

The POND II study period consisted of 6 weeks (July 19−August 26, 1999) with monitoring from Monday morning through Friday morning, with the inclusion of one weekend (August 6−8) that provided 11 contiguous days of data for the POND II database. Each passive ozone station deployed the following samplers daily: one 24-h passive sampling

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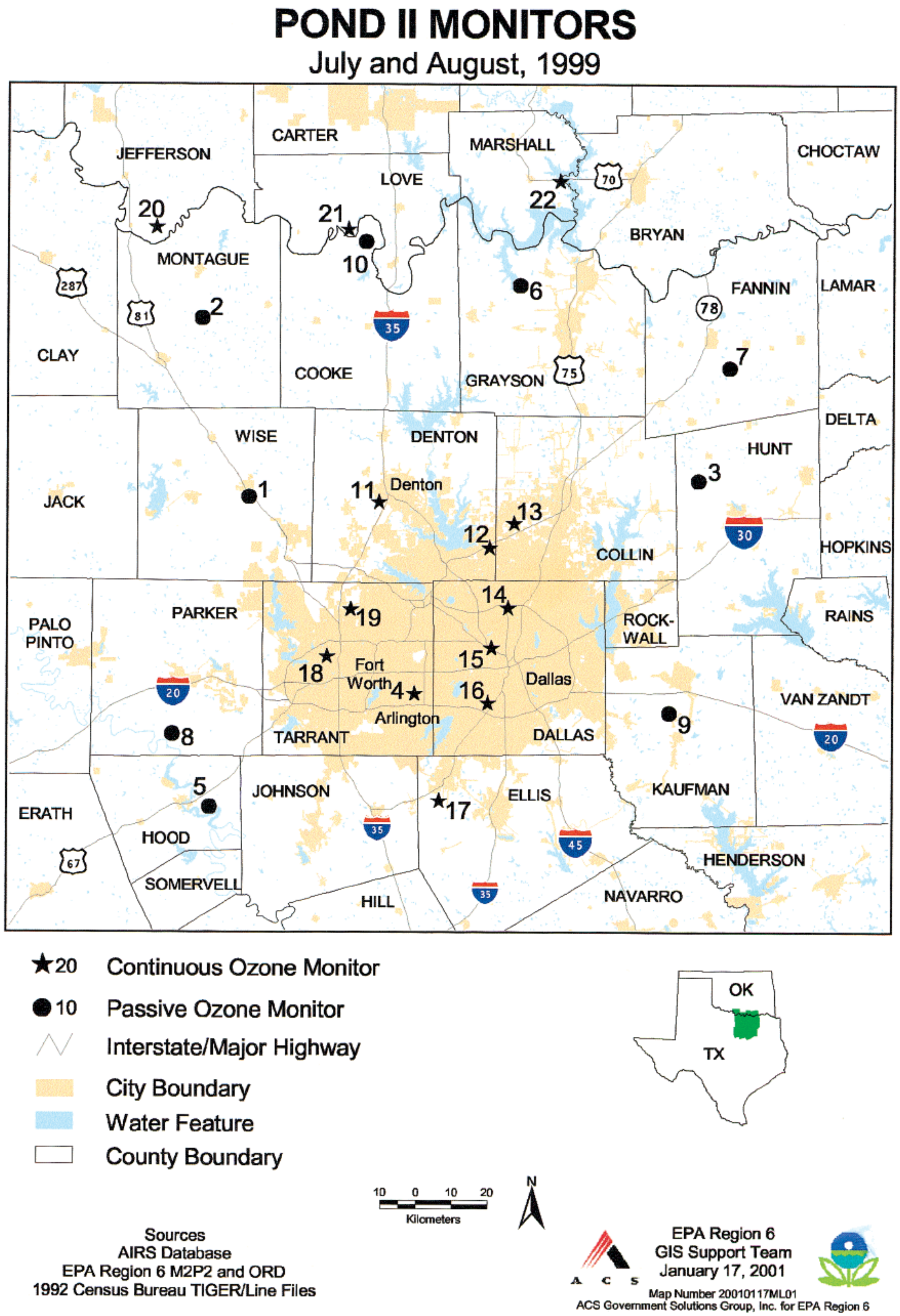


FIGURE 1. Twenty-two site map of the Passive Ozone Network of Dallas (POND) 1999 study.

device (PSD), two 12-h day PSDs, and two 12-h night PSDs. Both 12-h and 24-h passive ozone sampling was conducted so that sampling began at 7:00 AM ($\pm$ 30 min) local daylight time (LDT) each day. The duplicate 12-h sampling was used to establish the precision of the bidaily measurements. The National Exposure Research Laboratory (EPA) in North Carolina supplied and analyzed the networked PSDs on a weekly basis.

As during the POND I study, the PSDs and coated disks used to collect ozone were obtained from Ogawa & Co., Inc., Pompano Beach, FL. All disks for this study were prepared 4 weeks before needed from a common source of $NaNO_2$

and stored at −20 °C until removed for preparation of PSD mailers. One of the ten POND II passive ozone samplers was collocated with a Dasibi Model 1008 continuous ozone sampler (site #4, the Arlington site). This site was also collocated in POND I; therefore, correlation results could be compared between the 1998 and 1999 summer ozone seasons. Each of the 10 passive ozone sites in the POND II network received a mailer containing 22 PSDs every week. Two unopened PSD controls accompanied each round-trip mailing.

Meteorological data were downloaded from the EPA Aerometric Information Retrieval System (AIRS) database for a central, representative site of the DFW area, the Arlington site (AIRS site #48-439-0057 and stipulated collocated POND II site #4). Parameters analyzed included resultant wind speed, resultant wind direction, and ambient temperature for each 24-h period as well as each 12-h period. The Arlington site meteorological data were also used in analyzing the POND I data.

Diurnal ozone data contour maps, in the form of 12-h three-dimensional (3D) contour maps, as well as 24-h two-dimensional (2D) contour maps were constructed for each day of the POND II study using ARCVIEW (GIS) Spatial Analyst software (*10*) with application of the inverse distance weighted (IDW) method for surface interpolation and 3-D Analyst. The IDW method determines values using a linearly weighted combination of sample points. County boundaries and major highway depictions were gathered from the 1992 Census Bureau TIGER/Line files.

3. Results and Discussion

3.1 Precision and Correlation. The precision for the 6 week POND II data was checked by analyses of all differences between the 12-h site duplicates. The absolute difference between the 12-h duplicates had a mean of 3.4 ppb ozone, a median of 2.6 ppb, and was less than 7.6 ppb in 90% of the cases.

The correlations between sites for the 12-h passive monitoring ozone concentrations were generally between 70% and 90% for daytime samples. The corresponding nighttime correlations were more variable and in the range of 50−80%. Correlations between the 24-h POND data and both the day and night 12-h POND data were generally high as expected. Day/24-h correlations at individual sites ranged between 83% and 96%, and night/24-h correlations were between 71% and 96%. Variations in these diurnal correlations were usually explained when the daily ozone contour maps for the region were examined with accompanying meteorological information.

To validate the POND II passive ozone data with continuous ozone data and to further expand the overall POND I/II database, the urban Arlington site (site #4) was collocated for passive/continuous ozone data comparison. During the POND I study, this site produced an r value of 0.97 when comparing the passive 24-h ozone values to the continuous 24-h ozone values. Three other passive/continuous collocated ozone sites during the POND I study recorded equally high r values from 0.95 to 0.97. For POND II, the Arlington site again recorded a high r value of 0.96 when comparing passive and continuous 24-h ozone samples, signifying continued confidence in the passive ozone data. Comparisons of the 12-h passive ozone data with continuous ozone data at the Arlington site also resulted in good correlations, with an r value of 0.85 for the 12-h day comparison and an r value of 0.94 for the 12-h night comparison. In addition, the 12-h passive ozone monitoring concentrations at the collocated Arlington site in the POND II study showed a high Pearson correlation coefficient of 0.79 with the 8-h daily ozone maxima from the site.

3.2 Comparisons of the 1998 and 1999 POND Studies. One of the exercises conducted during the 1998 POND I study involved analyzing 24-h passive ozone samples on 8-h ozone standard exceedance days. For 11 8-h ozone exceedance days in 1998, the average 24-h PSD value calculated from the four collocated passive/continuous sites was 49.6 ppb ± 9.7 ppb. For the 1999 POND II study, there was one collocated site in Arlington (site #4), and on seven 8-h ozone exceedance days at this site the average 24-h PSD value was 58.9 ppb with a standard deviation of 9.5 ppb. Regarding days on which the 8-h ozone standard was exceeded, the following observations from collocated data are noteworthy: (i) the PSDs yielded averages, 49.6 ppb (1998 average) and 58.9 ppb (1999 average), within one standard deviation of each other; (ii) the standard deviations are almost the same for each year, and (iii) 58.9 ppb, the average 24-h PSD value for 8-h exceedance days in 1999, falls within the 95% prediction interval for the 85 ppb trigger level established from the 1998 data in the POND I paper (*9*). Given that 1999 was a higher ozone year than 1998 (i.e., the continuous ozone monitors in the area recorded higher average ozone concentrations in 1999 compared to 1998), the observations strongly suggest that PSDs provide a reliably consistent monitoring methodology.

Additionally, when all days are considered, the POND II data from the collocated site at Arlington show a Pearson correlation coefficient of 0.90 between the 24-h passive monitoring ozone concentrations and the 8-h ozone maximum concentrations from the continuous monitor. Furthermore, the POND I study established 36.1 ppb as the lower limit of the 95% prediction interval for the passive ozone monitor concentration corresponding to an 8-h continuous ozone maximum concentration of 85 ppb. Applying this result to the 1999 POND II data, there were 7 days when the PSD gave a "false positive"; that is, the PSD suggested, based on the lower limit of the 95% prediction interval, that a violation occurred, but the continuous ozone monitor did not report an 8-h ozone maximum of 85 ppb or greater. However, one finds that in each of the seven instances when an exceedance of the 8-h ozone standard occurred (and the passive ozone data were present), the PSD "found" the violation; in no case did the PSD fail to indicate a violation when one occurred at the Arlington site. On 9 days, the PSD and continuous monitor were in agreement that no violation of the 8-h ozone standard occurred. Thus, whether focusing on exceedance days only or considering the full suite of monitored days, these results suggest that the passive monitors can provide reliable indicators of when violations of the 8-h ozone standard may occur.

The POND II study went beyond POND I by also collecting diurnal PSD data, i.e., 12-h day and 12-h night samples were taken. Data generated by the day and night PSDs were to provide a finer assessment of the timing and duration of ozone events as depicted by the longer time-averaged 24-h PSD data. On the seven 8-h ozone exceedance days at the Arlington site in 1999, the average 12-h day PSD value was 64 ppb with a standard deviation of 5 ppb. The minimum 12-h day PSD recorded during the seven 8-h ozone exceedance days was 57 ppb, and the maximum 12-h day PSD value recorded was 71 ppb.

An important benefit of the two POND studies is that a multitude of ozone data have been collected in the DFW Metroplex region on many ozone standard exceedance days. Table 1 displays the number of both 1-h and 8-h ozone standard exceedance days during both POND studies which should be valuable to modelers and air quality scientists working on the DFW Metroplex ozone pollution problem. The table also shows the importance of conducting long studies, in this case 6−8 weeks, to capture a sufficient amount of data on ozone standard exceedance days.

TABLE 1. Comparison of Ozone Exceedance Days during POND I and POND II

study	dates of study	# 1-h ozone exceedance days	range of max. 1-h values (ppb)	# 8-h ozone exceedance days	range of max. 8-h values (ppb)	range of max. 24-h PSD values (ppb)
POND I	July 13−Sept 3, 1998	3	125−152	11	85−126	40−72
POND II	July 19−Aug 26, 1999	10	125−164	15	85−135	48−79

3.3 Ozone Contour Mapping of POND II Data. Diurnal ozone data contour maps, in the form of 12-h 3D contour maps, as well as 24-h 2D contour maps were constructed for each day of the POND II study. In viewing these maps, the reader is cautioned that some uncertainty is associated with the predicted ozone concentrations. This uncertainty will be greatest in the areas with the fewest monitors and near the boundary of the mapped area. Notwithstanding this uncertainty regarding the specific values, the maps provide a good guide to relative ozone concentrations across the region. It is beyond the scope of this article to display all contour maps for the study period, but the entire POND I and POND II database are scheduled to be released as public information, and the data can currently be requested from any of the authors. Figures 2a−l provide ozone mapping of four consecutive days that exceeded both the 1-h and 8-h ozone standards (August 16−19, 1999) as measured in the regulated DFW urban core. On the left-hand side of the page for each day is the 2D contour of the 24-h ozone concentrations that shows the county boundaries for the region. On the right-hand side are 12-h day and 12-h night 3D ozone contours that focus upon diurnal spatial ozone changes with major roadways displayed. As referenced above from the POND I study, an observer can scan each 24-h map for values of 50 ppb ± 10 ppb for possible 8-h ozone standard exceedances. In addition, an observer can also scan each 12-h day map for values 60 ppb or greater for possible 8-h ozone standard exceedances.

During the day on August 16 winds were out of the east, and the 12-h day 3D contour in Figure 2b clearly shows the highest ozone concentrations in the western portion of the monitored region. The 12-h night 3D contour clearly shows the effects of city ozone scavenging by depicting the lowest ozone concentrations in the core of Dallas and Fort Worth. The highest ozone concentrations were recorded on August 17 across the entire monitored region with light southerly winds. Note also the high night ozone concentrations at the southern and northern more rural areas of the monitored region. Light southerly winds continued into August 18 with the highest ozone concentrations in the northern portion of the monitored region. A wind flow reversal from the north occurred early on August 19, causing very high ozone concentrations to be recorded at the Midlothian (Ellis County) continuous ozone sampler (site #17) and at the Hood County passive ozone sampler (site #5). Average 12-h day temperatures on all days were >= 90 °F. Note that some rural areas in the region were exposed to night concentrations as high as 73 ppb (August 17), meaning that some agricultural crops were exposed to significant ozone concentrations for 24 h, not just to the very high ozone concentrations measured by the PSDs during the day.

All areas of ozone concern were adequately displayed by the 24-h ozone samplings. However, the diurnal samplings provide the modeler a better perception of ozone intensities and persistence throughout the day within the region. This observation suggests the selection of ozone PSD sampling duration and frequency for the evaluation of a new region might be a two-step process, i.e., daily sampling followed by diurnal networked sampling, or a simultaneous sampling mixture might be warranted. This passive ozone monitoring approach can be very adaptive to the characteristics of a region and can respond to the particular data needs of the modeler or monitoring siting specialist.

3.4 Assessment of Urban/Rural Site Classifications. The POND II study benefitted from three rural monitoring sites set up by the State of Oklahoma just across the Texas state line from the northernmost POND II sites in Montague, Cooke, and Grayson Counties. Having these continuous ozone sites helped track the DFW Metroplex ozone plume on days with predominate southerly winds. During the POND II study, there were 3 days with southerly wind flow during which at least one of the Oklahoma monitors recorded a maximum 8-h ozone value above 84 ppb, clearly demonstrating that the geographic extent of the DFW ozone plume can reach out to at least 130 km (80 miles).

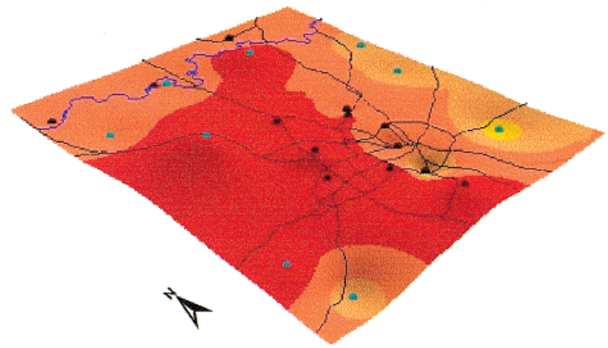
The magnitude of anthropogenic pollution influence on all continuous ozone monitors in the South Central U.S. (i.e., New Mexico, Texas, Oklahoma, Arkansas, and Louisiana) was examined by comparing the ratio of the daily 1-h ozone maximum (H1) to the daily 1-h ozone minimum (L1). As suggested by Saylor et al. (*11*), a ratio of less than 4 identifies a good rural site, i.e., a site not directly influenced by urban and industrial emissions. Table 2 displays 1 h ratios for the continuous ozone monitors in the POND II study and for ozone sites at Big Bend National Park and the Ozark National Forest.

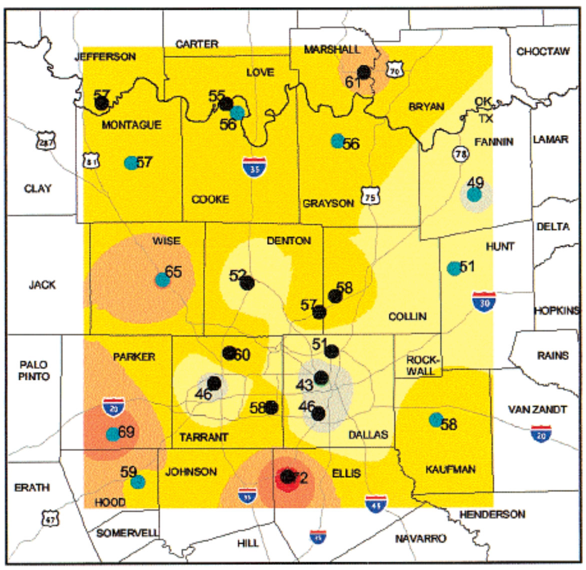
It is notable that none of the continuous POND II sites recorded mean 1-h ratios less than 4 (i.e., less than 3.5; reference Table 2), although the Midlothian site (#17) and the three Oklahoma sites recorded mean ratios from 4 to 5. This is consistent with the concept that these continuous instrumented sites are located in areas that are still influenced by urban pollution. Consequently, in the South Central U.S., the only "true" or reference rural continuous sites as defined by the Saylor et al. criterion are the Big Bend National Park ozone site in Texas and the Ozark National Forest ozone site in Arkansas, both with low mean ratios of 2. These low mean ratios are reflective of a generally flat ozone diurnal profile and thus a negligible impact from locally generated ozone (*12*−*14*). To compare these two reference rural continuous ozone sites to the passive ozone sites in POND II, a ratio was taken of the 12-h daytime ozone value (12D = 7 AM − 7 PM LDT) to the 12-h nighttime ozone value (12N = 7 PM − 7 AM LDT). The Ozark 12D/12N mean ratio was 1 with a range of 0.8−1.4, while the Big Bend 12D/12N mean ratio was similar at 1.1 with a range of 0.7−1.5. Therefore, as the 12D/12N mean ratio gets closer to 1 (and correspondingly as the H1/L1 mean ratio gets closer to 2), there should be less influence of anthropogenic pollution sources on a monitoring site.

Table 2 shows the breakdown of 12D/12N ratios for the 22 POND II sites, plus the Ozark and Big Bend sites as rural reference sites. Each of the 22 POND II sites were classified as either urban or rural. The urban classification applied to monitors in areas with high population density and negligible agricultural acreage, while the rural classification applied to monitors in areas with much lower population density and significant agricultural acreage. It is important to note that 9 of the 10 POND II passive ozone sites were purposely sited in the rural periphery of the DFW Metroplex, i.e., in areas with lower population density and more agricultural acreage. Only the collocated passive/continuous ozone site in Ar-

POND II CONTOURS

August 16, 1999





12-Hour Day

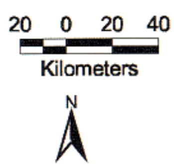
Dominant resultant wind direction:	SE/NE
Average resultant wind speed (mph):	6
Low 12-hr ozone value (ppb):	58
High 12-hr ozone value (ppb):	87
Average temperature (Deg. F):	90
Number of monitors reporting:	22

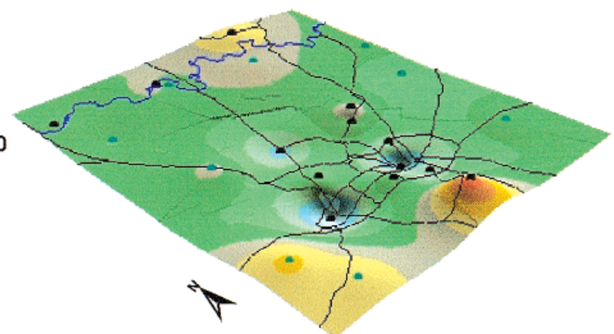
Figure 2b

24-Hour

Dominant resultant wind direction:	SE/NE
Average resultant wind speed (mph):	5
Low 24-hr ozone value (ppb):	43
High 24-hr ozone value (ppb):	72
Average temperature (Deg. F):	86
Number of monitors reporting:	22

Figure 2a





12-Hour Night

Dominant resultant wind direction:	SE
Average resultant wind speed (mph):	5
Low 12-hr ozone value (ppb):	17
High 12-hr ozone value (ppb):	67
Average temperature (Deg. F):	83
Number of monitors reporting:	22

Figure 2c

Value Ranges (ppb)

- Less than 20
- 20 - 24
- 25 - 29
- 30 - 34
- 35 - 39
- 40 - 44
- 45 - 49
- 50 - 54
- 55 - 59
- 60 - 64
- 65 - 69
- 70 - 79
- 80 - 89
- 90 - 99
- 100 or Greater

Daily values rounded to the nearest integer. Contours are shaded in ranges of 5 ppb.

All ozone data analyzed from 7am to 7pm and 7pm to 7am local daylight time. All meteorological data analyzed from 7am to 7pm and 7pm to 7am local daylight time from site #4 in Arlington (48-439-0057).

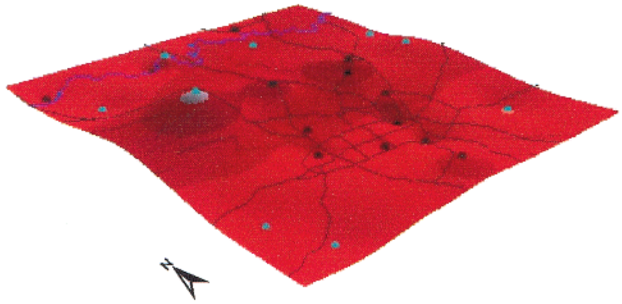
- Continuous Ozone Monitor
- Passive Ozone Monitor
- Interstate/Major Highway
- Red River

OK
TX

Sources
AIRS Database
EPA Region 6 M2P2 and ORD
1992 Census Bureau TIGER/Line Files

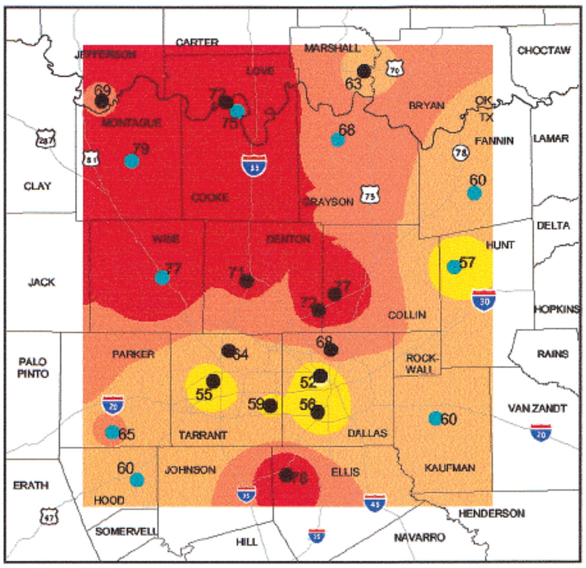
EPA Region 6
GIS Support Team
January 31, 2001
Map Number 20010131ML01
ACS Government Solutions Group, Inc. for EPA Region 6

POND II CONTOURS
August 17, 1999



12-Hour Day	
Dominant resultant wind direction:	SW/SE
Average resultant wind speed (mph):	4
Low 12-hr ozone value (ppb):	70
High 12-hr ozone value (ppb):	102
Average temperature (Deg. F):	90
Number of monitors reporting:	22

Figure 2e

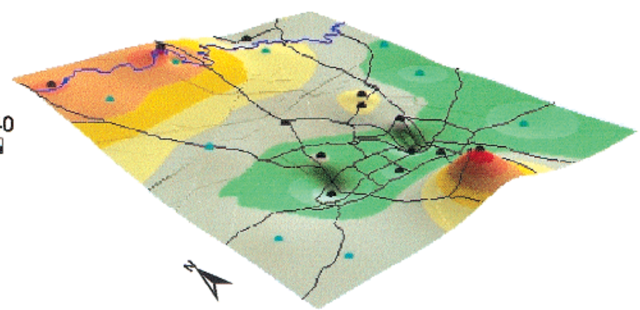


24-Hour	
Dominant resultant wind direction:	SW/SE
Average resultant wind speed (mph):	4
Low 24-hr ozone value (ppb):	52
High 24-hr ozone value (ppb):	79
Average temperature (Deg. F):	88
Number of monitors reporting:	22

Figure 2d

20 0 20 40
Kilometers

N



12-Hour Night	
Dominant resultant wind direction:	SE
Average resultant wind speed (mph):	4
Low 12-hr ozone value (ppb):	30
High 12-hr ozone value (ppb):	73
Average temperature (Deg. F):	85
Number of monitors reporting:	22

Figure 2f

Value Ranges (ppb)
- Less than 20
- 20 - 24
- 25 - 29
- 30 - 34
- 35 - 39
- 40 - 44
- 45 - 49
- 50 - 54
- 55 - 59
- 60 - 64
- 65 - 69
- 70 - 79
- 80 - 89
- 90 - 99
- 100 or Greater

Daily values rounded to the nearest integer. Contours are shaded in ranges of 5 ppb.

All ozone data analyzed from 7am to 7pm and 7pm to 7am local daylight time. All meteorological data analyzed from 7am to 7pm and 7pm to 7am local daylight time from site #4 in Arlington (48-439-0057).

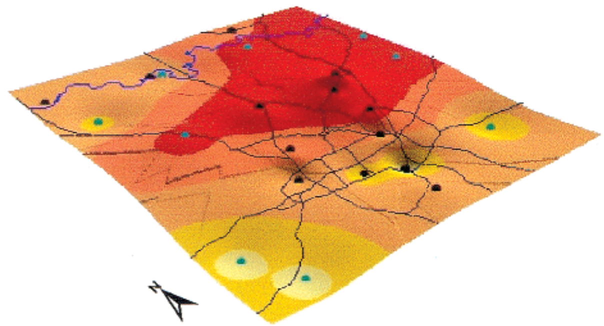
- Continuous Ozone Monitor
- Passive Ozone Monitor
- Interstate/Major Highway
- Red River

Sources
AIRS Database
EPA Region 6 M2P2 and ORD
1992 Census Bureau TIGER/Line Files

OK
TX

EPA Region 6
GIS Support Team
January 31, 2001
A C S
Map Number 20010131ML02
ACS Government Solutions Group, Inc. for EPA Region 6

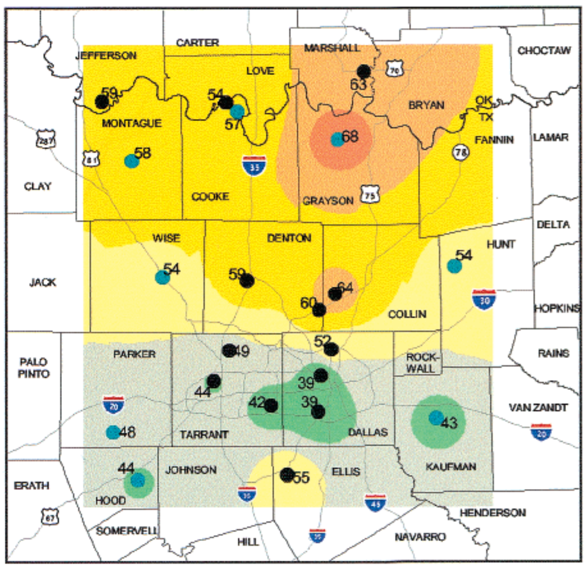
POND II CONTOURS
August 18, 1999



12-Hour Day

Dominant resultant wind direction:	SE
Average resultant wind speed (mph):	4
Low 12-hr ozone value (ppb):	52
High 12-hr ozone value (ppb):	84
Average temperature (Deg. F):	92
Number of monitors reporting:	22

Figure 2h



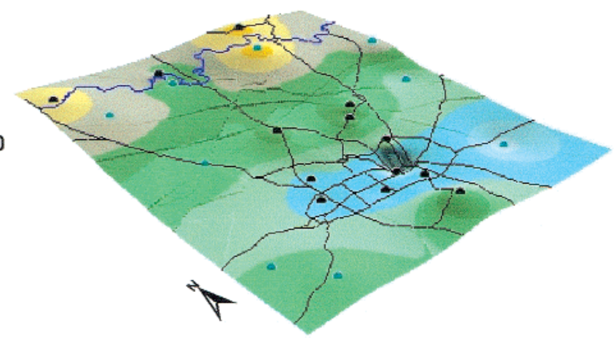
24-Hour

Dominant resultant wind direction:	SE/SW
Average resultant wind speed (mph):	4
Low 24-hr ozone value (ppb):	39
High 24-hr ozone value (ppb):	68
Average temperature (Deg. F):	90
Number of monitors reporting:	21

Figure 2g

20 0 20 40
Kilometers

N



12-Hour Night

Dominant resultant wind direction:	SE/SW
Average resultant wind speed (mph):	4
Low 12-hr ozone value (ppb):	15
High 12-hr ozone value (ppb):	57
Average temperature (Deg. F):	88
Number of monitors reporting:	22

Figure 2i

Value Ranges (ppb)
- Less than 20
- 20 - 24
- 25 - 29
- 30 - 34
- 35 - 39
- 40 - 44
- 45 - 49
- 50 - 54
- 55 - 59
- 60 - 64
- 65 - 69
- 70 - 79
- 80 - 89
- 90 - 99
- 100 or Greater

Daily values rounded to the nearest integer. Contours are shaded in ranges of 5 ppb.

All ozone data analyzed from 7am to 7pm and 7pm to 7am local daylight time. All meteorological data analyzed from 7am to 7pm and 7pm to 7am local daylight time from site #4 in Arlington (48-439-0057).

- Continuous Ozone Monitor
- Passive Ozone Monitor
- Interstate/Major Highway
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Sources
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EPA Region 6
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January 31, 2001
Map Number 20010131ML03
ACS Government Solutions Group, Inc. for EPA Region 6

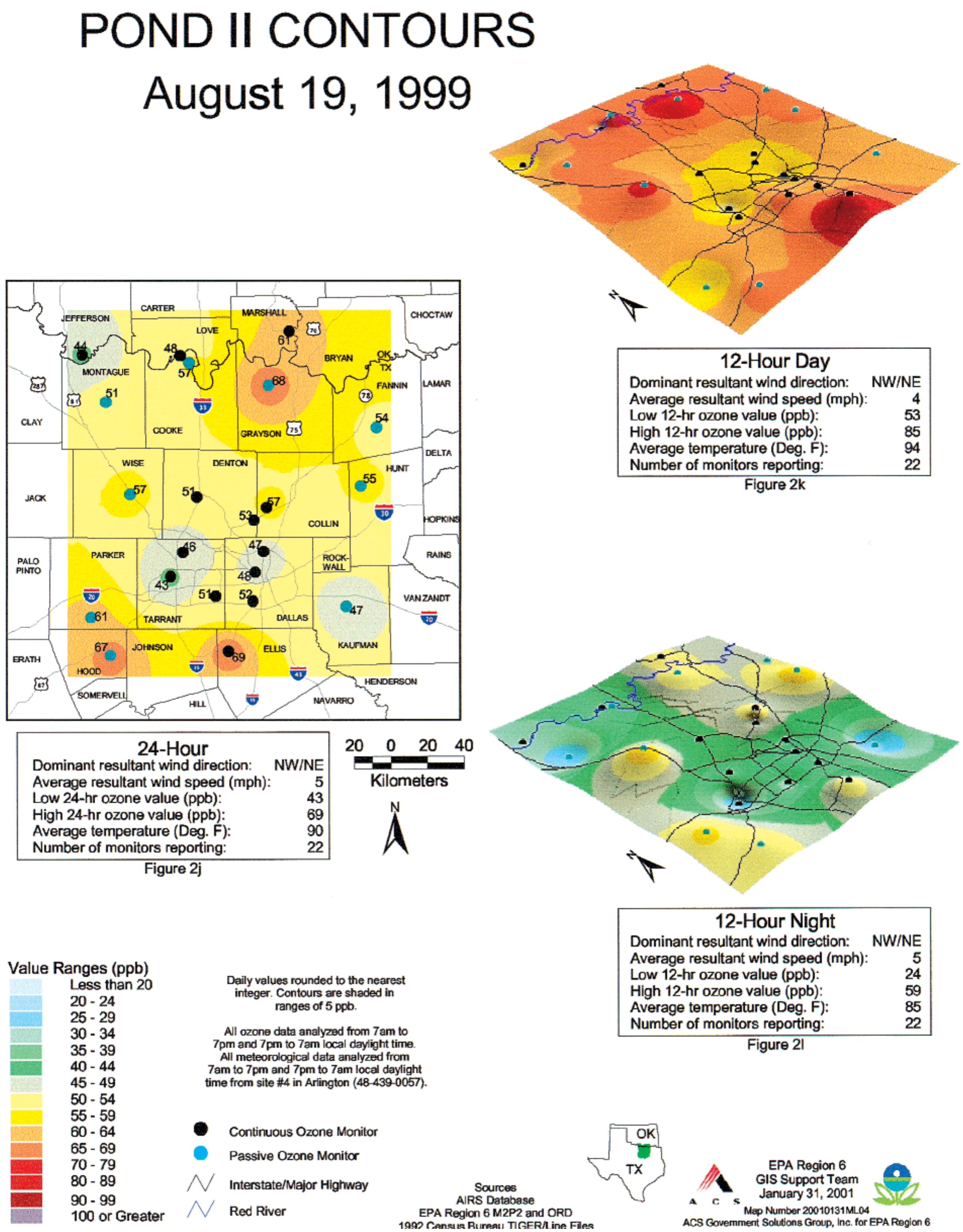

FIGURE 2. (a−l) Selected ozone contour maps generated from the 22-site passive/continuous ozone monitoring network.

lington was perceived as an urban site. With this information in mind, and by scanning Table 2, one notices that all 12D/12N ratios <= 1.4 were recorded at sites perceived as rural and that a majority (64%) of 12D/12N ratios >= 1.5 were recorded at sites perceived as urban. In addition, the data suggests that five passive ozone sites located in the rural periphery of the DFW Metroplex (i.e., passive ozone sampling sites in Cooke, Fannin, Wise, Kaufman, and Hunt Counties) were more impacted by anthropogenic pollution than the passive ozone sampling sites in Parker, Hood, Montague, and Grayson Counties. Thus, the POND II study demonstrated that 12-h passive ozone data could be used to assess the relative magnitude of anthropogenic pollution influence on a monitoring site, even when the studied region contained a centrally located strong urban influence.

3.5 Other Significant Information. The POND I and II studies have demonstrated the valuable use of passive ozone data in a large urban/rural region (e.g., the Dallas−Fort Worth

TABLE 2. Comparison of POND II Passive/Continuous Ozone Sites to Reference Rural Sites[a]

site location	ozone monitoring method	site classification	mean 12D/12N ratio	12D/12N range	mean H1/L1 ratio	H1/L1 range
Ozark National Forest, Arkansas	continuous	reference rural	1.0	0.8−1.4	1.6	1.2−2.1
Big Bend National Park, Texas	continuous	reference rural	1.1	0.7−1.5	1.7	1.3−2.7
#8 Parker Co.	passive	rural	1.2	0.8−3.8	na	na
#17 Ellis Co.	continuous	rural	1.2	0.8−1.7	3.9	1.5−11.8
#20 Jefferson Co., Oklahoma	continuous	rural	1.3	0.8−2.2	5.1	1.8−26.7
#21 Love Co., Oklahoma	continuous	rural	1.3	0.8−1.8	4.4	1.9−9.0
#5 Hood Co.	passive	rural	1.3	0.9−1.9	na	na
#22 Marshall Co., Oklahoma	continuous	rural	1.4	0.8−2.0	4.6	2.1−21.3
#2 Montague Co.	passive	rural	1.4	0.7−3.8	na	na
#6 Grayson Co.	passive	rural	1.4	0.8−2.2	na	na
#10 Cooke Co.	passive	rural	1.5	0.8−2.8	na	na
#4 Tarrant Co.	continuous	urban	1.5	0.9−3.4	48.9	2.8−163.0
#19 Tarrant Co.	continuous	urban	1.6	1.0−2.3	27.9	2.4−113.0
#7 Fannin Co.	passive	rural	1.7	1.0−2.7	na	na
#1 Wise Co.	passive	rural	1.7	1.2−3.1	na	na
#12 Denton Co.	continuous	urban	1.7	1.0−3.9	20.8	3.4−105.0
#13 Collin Co.	continuous	urban	1.7	0.9−2.6	28.0	3.7−87.0
#16 Dallas Co.	continuous	urban	1.7	1.2−2.3	44.9	3.2−122.0
#11 Denton Co.	continuous	urban	1.8	1.3−2.8	29.3	3.1−147.0
#14 Dallas Co.	continuous	urban	1.8	1.2−3.6	29.7	3.1−111.0
#18 Tarrant Co.	continuous	urban	1.9	1.0−4.4	32.4	2.5−132.0
#9 Kaufman Co.	passive	rural	2.0	1.3−2.9	na	na
#3 Hunt Co.	passive	rural	2.1	1.1−4.2	na	na
#15 Dallas Co.	continuous	urban	2.5	1.4−7.1	60.8	5.2−141.0

[a] 12D = 7AM-7PM LDT ozone concentration; L1 = daily min. 1-h ozone concentration; 12N = 7PM-7AM LDT ozone concentration; reference rural as defined by Saylor et al. (*11*); H1=daily max. 1-h ozone concentration; na = not applicable.

Metroplex and surrounding rural periphery) where air quality is increasingly impacted by elevated lower tropospheric ozone concentrations. Because the passive ozone data compared so favorably to the continuous ozone monitoring data, the ozone concentrations obtained from passive 24-h and 12-h samplers could be readily analyzed alongside the continuous data. By adding passive ozone samplers to the continuous ozone monitors operated by the State of Texas, State of Oklahoma, and City of Dallas government agencies, 36 sites with ozone data were analyzed in 1998, and 22 sites with ozone data were analyzed in 1999. With 14 weeks of extensive, verified high quality ozone data representing two high ozone seasons over an approximate 25 000 km^2 region, scientists running future models of ozone pollution in the DFW Metroplex have ambient measurements from over two dozen ozone exceedance days with which to both develop and verify state implementation plans for ozone pollution management. Also importantly, the ability of the public operators to successfully perform the functions associated with greater sampling frequency and complexity in the POND II data collection was clearly demonstrated at each network site.

The POND II data set also includes a weekend (August 6−8, 1999) which can be compared to weekday data. These weekend data were taken during a 9-day period (August 2−10, 1999) in which at least one monitor in the DFW region recorded a daily 8-h ozone exceedance over 84 ppb. Ozone 8-h concentrations exceeding the new standard were recorded on Saturday, August 7, across the DFW region, reaching up to the Oklahoma Red River sites and even extending to the reference rural Arkansas Ozark National Forest site, which recorded a maximum 8-h ozone concentration of 85 ppb. The Ozark site is located about 500 km northeast of the DFW Metroplex. Clearly, this multiregional elevated ozone weekend episode is a good candidate for future detailed modeling analysis.

The POND data have been very useful in reviewing the DFW region continuous ozone monitoring network. Indeed, recommendations for additional ozone monitoring in the region were based in part on results of the POND studies. During the summer of 2000, eight monitors were added to the DFW ozone network by the State of Texas and City of Dallas government agencies, many in counties outside of the "core four" 1-h nonattainment counties (Dallas, Tarrant, Collin, and Denton). Thus, the DFW Metroplex ozone network has nearly doubled in size, into areas suggested and validated by the POND 2-year study.

In an earlier discussion it was indicated that high ozone concentrations were recorded as far as 130 km (80 miles) from the DFW Metroplex core in rural southern Oklahoma. Based upon these data, the State of Oklahoma plans to operate new ozone sites further north from their 1999 sites bordering the Red River to further assess the northward movement of ozone plumes from the DFW Metroplex during periods of predominant southerly winds.

The POND studies provide rural ozone data which could be used by researchers evaluating crop damage from ozone pollution. The data from POND I and POND II have shown that ozone levels exceeding the national standards can reach out far from the DFW urban core into agricultural areas that are economically dependent upon significant acreage of cotton, wheat, and corn, all ozone-sensitive crops (*15*, *16*). The ecological effects of this ozone air pollution may result in lowered crop yields, and the resultant crop product quality may be lessened due to a reduced resistance to disease and inclement weather.

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